

SECTION 8

PERFORMANCE OF THE CONTROL AND TREATMENT OPTIONS

8.1 Introduction

This discusses the treatment performance data collected and available to the Agency for the treatment technologies discussed in 7 and for the constituents and pollutant parameters to be regulated discussed in 6. The subsections below list, by technology, criteria applied to available datasets to determine which data corresponded to well-designed/well-operated treatment units that are used in developing long-term mean (LTM) performance levels. Those data meeting the criteria are presented in this section.

The following information is presented in this section:

- 8.2 provides an overview of the treatment performance databases developed by the Agency and their sources.
- 8.3 provides a technology-by-technology evaluation of treatment performance data, lists the criteria used to identify data associated with well-designed/well-operated systems, and summarizes those datasets that meet the well-designed/well-operated criteria.
- 8.4 presents the Agency's rationale for the data transfers developed for this regulation, including process simulation modeling conducted by EPA to support transfers.
- 8.5 discusses the development of LTMs for conventional pollutants and COD.
- 8.6 discusses the development of the LTM for cyanide.
- 8.7 discusses the development of LTMs for priority and nonconventional pollutants.
- 8.8 discusses the development of the LTM for ammonia.

8.2 Treatment Performance Databases

There are four main sources of treatment performance data available to the Agency: EPA sampling data; industry-supplied self-monitoring data; data gathered from EPA-sponsored treatability studies; and data collected as part of other research efforts. These sources are described in detail in 3.2. The treatment performance data used from these sources are discussed in greater detail below.

8.2.1 EPA Pharmaceutical Manufacturers Sampling Program Data

Beginning in 1978, EPA conducted the Screening and Verification Sampling Programs. Under these programs, wastewater samples were collected from plants with manufacturing operations representative of the pharmaceutical manufacturing industry. In the screening program, in-plant and end-of-pipe wastewater samples from 26 plants were screened for the presence of 129 priority pollutants. Typical sample collection periods were 24 hours during the screening phase. The Agency conducted follow-up sampling (referred to as the verification phase) at five facilities to verify the presence, levels, frequency of discharge, and treatability of the pollutants detected during the screening program. The typical verification sampling program was three days in length.

Between 1983 and 1991, EPA also conducted 15 different sampling episodes at 13 pharmaceutical manufacturing facilities. Data were collected for all pollutants on the List of Analytes during these sampling efforts. These data were used to characterize the pollutants in the wastewater discharged by direct and indirect facilities, to generate pollutant treatment system performance data from facilities with well-operated biological treatment systems, and to obtain treatability data characteristic of the operation of steam stripping columns.

The treatment performance data collected from these sampling episodes were incorporated into a sampling database. These data were evaluated against the criteria defined in 8.3 to establish data representative of well-designed/well-operated steam stripping, and biological treatment systems for priority and nonconventional pollutants.

8.2.2 Industry-Supplied Self-Monitoring Data

Self-monitoring data were supplied by pharmaceutical manufacturers to the Agency as part of their response to the Detailed Questionnaire (self-monitoring data were also submitted by the seven facilities that participated in the 1989 pretest questionnaire). In addition, the Agency requested self-monitoring data from Facility 30542 on the performance of their cyanide destruction unit, which employs in-plant hydrogen peroxide oxidation treatment. Several pharmaceutical facilities also submitted self-monitoring data with their comments on the Proposed Pharmaceutical Effluent Guidelines and Limitations and the Notice of Availability. All self-monitoring treatment performance data were evaluated against the criteria defined in 8.3 to establish data representative of well-designed/well-operated treatment units. Data that conformed to the criteria were placed into the Self-Monitoring Database. This database includes biological treatment performance data for conventional, priority, and nonconventional pollutants as well as cyanide treatment performance data. EPA also has TSS industry-supplied self-monitoring data in connection with multi-media filtration and polishing pond treatment.

8.2.3 EPA Treatability Studies Data

In 1984, the Agency collected granular activated carbon treatability data for total COD. The data collected as part of this treatability study were evaluated to establish data representing well-designed/well-operated GAC treatment for COD.

In late 1991, the Agency collected steam stripping treatability data for several volatile organic pollutants generated at a pharmaceutical manufacturing facility using a pilot-scale and bench-scale steam stripper. Additionally, the Agency collected distillation treatability data in September of 1993 for methanol, using an existing full-scale distillation column in operation at a pharmaceutical manufacturing facility. The data collected as part of these treatability studies were evaluated against the criteria defined in 8.3 to identify data representative of well-designed/well-operated steam stripping and distillation treatment for priority and nonconventional pollutants.

8.2.4 Other Research Sources

In 1979, the Robert S. Kerr Environmental Research Laboratory at Ada, Oklahoma conducted an applied research study to determine the fate of specific priority pollutants within a biological treatment system.(1) In the course of the study, priority pollutants associated with the manufacture of pharmaceuticals were identified at two industrial facilities. The data collected as part of this study were evaluated against the criteria defined in 8.3 to identify data representative of well-designed/well-operated biological treatment for priority pollutants.

8.3 Evaluation of Treatment Performance Data

This subpresents the criteria used to evaluate well-designed/well-operated performance for each technology. The treatment performance data that meet these editing criteria are also presented below.

8.3.1 Advanced Biological Treatment

The Agency has defined "advanced" biological treatment at pharmaceutical manufacturing facilities as those with existing BPT-level performance or better, for treating BOD₅ and COD. Advanced biological treatment performance was defined in 7.2.2.1 as systems that consistently surpass, on a long-term basis, 90% BOD₅ reduction and 74% COD reduction from raw waste levels in pharmaceutical manufacturing wastewater, as required by the existing BPT effluent limitations guidelines (40 CFR Part 439).

These reductions in BOD₅ and COD represent the initial criteria used to identify best performer datasets for advanced biological treatment. For BOD₅, COD, and TSS, an additional criteria established for best performer datasets was that the treatment system represented by the data treat a predominant amount (49% or more by volume) of pharmaceutical process wastewater in relation to other process wastewaters treated by the system. In response to comments on the proposed rulemaking, EPA has used only treatment performance data collected from biological treatment systems that contain less than 25% nonprocess water to calculate long-term mean

performance. This data exclusion is based on the previous EPA effluent limitations guidelines and standards rulemaking for the Organic Chemicals, Plastics and Synthetic Fibers (OCPSF) industry (52 FR 42522) and ensures that the data used are representative of process wastewater treatment without undue dilution from nonprocess water sources.

Table 8-1 presents the BOD₅, COD, and TSS datasets that meet the criteria listed above for best performance. A review of these datasets shows that each is consistently achieving far greater reductions in BOD₅, COD, and TSS discharges than the other plants subject to the existing BPT regulations. Facilities 30010, 30540, and 30623 represent best treatment performance for conventional pollutants and COD for Subcategory A and C facilities. Facility 30637 represents best treatment performance for conventional pollutants and COD for Subcategory B and D facilities.

For the identification of applicable datasets for organic pollutants, the facility must achieve BOD₅ and COD removal representative of "advanced" biological treatment. Additional review criteria included:

- The treatment facility must process a predominant amount of pharmaceutical process wastewater compared to other process wastewater. A predominate amount is defined as $\geq 49\%$;
- The data should be for a constituent or pollutant parameters selected for regulation or to be used as a data transfer;
- The data must be representative of advanced biological treatment technology (e.g., datasets representing biological treatment plus powdered activated carbon adsorption were removed from consideration);
- The data from facilities that supplied influent data only should be excluded;
- The data must be from facilities where the average influent pollutant concentration was at least 10 times greater than the analytical detection limit so that treatment being achieved could be measured;
- The facility must treat less than 25% nonprocess water through the biological treatment facility; and

- The data must be from sampling events consisting of three or more data points.

Table 8-2 presents the organic constituent datasets that meet the criteria listed above for best performance. For organic constituents, treatment performance data do not demonstrate a difference in treatment based on subcategory, and were considered together. These data are considered representative of treatment performance for all subcategories.

8.3.2 Nitrification

The Agency has evaluated single and two-stage biological treatment at pharmaceutical manufacturing facilities to identify nitrification performance data. Nitrification can be accomplished in either a single or two-stage activated sludge system. Two indicators of nitrification are the presence of ammonia oxidizing bacteria and nitrite oxidizing bacteria, and analysis of the nitrogen balance to determine if nitrifying bacteria reduce the amount of ammonia and increase the amount of nitrite and nitrate. 7.2.2.1 identified common design criteria for single and two-stage systems with nitrification capability. In EPA's evaluation of its one stage biological treatment data, some systems were found to nitrify part of the time. In these cases, EPA considered in its nitrification database those data points associated with nitrification behavior. The treatment performance demonstrated by the edited data sets closely resembles the treatment performance of the data sets which exhibited consistent nitrification. Table 8-3 presents the nitrification treatment performance data that represent nitrification. All of this performance data is taken from biological treatment systems achieving at least 90% BOD₅ removal and 74% COD removal.

8.3.3 Multimedia Filtration

The Agency has obtained industry-supplied self-monitoring treatment performance data for tertiary filtration from one Subcategory A and C pharmaceutical manufacturing facility (Facility 50007) and from two Subcategory B and D pharmaceutical manufacturing facilities (Facilities 12053 and 12317). TSS reductions through treatment were calculated using these data; datasets

that did not include influent concentrations were not included in the calculations. Table 8-4 presents the data that describe the treatment performance of these tertiary filters.

8.3.4 Polishing Ponds

The Agency has obtained industry-supplied self-monitoring treatment performance data describing polishing pond treatment from one Subcategory A and C pharmaceutical manufacturing facility. TSS reductions through treatment were calculated using these data. The calculated reductions were used in developing the TSS LTM representing polishing pond treatment. Table 8-5 presents the polishing pond treatment performance data.

8.3.5 Cyanide Destruction

The Agency requested cyanide destruction data in the Detailed Questionnaire. Ten facilities reported using cyanide destruction systems, including the following types of treatment: hydrogen peroxide oxidation (at 3 facilities), alkaline chlorination (at 6 facilities), and hydrolysis (at 1 facility). EPA considered all of the individual datasets representative of the various cyanide destruction technologies in use. EPA considered two different technologies to represent achievable cyanide reduction: hydrogen peroxide oxidation and alkaline chlorination. Two technologies were considered because of the potential safety hazard hydrogen peroxide oxidation may cause when used to treat pharmaceutical cyanide wastewaters with high organic content. Hydrogen peroxide may be highly reactive with organic chemicals and may release oxygen in the chemical process which may combust causing unsafe working conditions. Alkaline chlorination on the other hand, does not release oxygen in the chemical process of converting cyanide to a nitrogen gas and carbonate.

As discussed in 3.2.5, EPA requested Facility 30542 to develop a long-term database documenting the performance of their hydrogen peroxide oxidation cyanide destruction unit. The facility submitted six months of data to EPA in November 1991. EPA also sampled the cyanide destruction unit of this facility during an on-site sample episode. The dataset that represents the performance of hydrogen peroxide oxidation was obtained from treatment batches with analytical

sampling of each treated batch to achieve a treated cyanide concentration $\leq 1\text{mg/L}$. Facility 30567 developed a long-term database documenting the performance of their alkaline chlorination unit. The facility submitted 1990 data with their detailed questionnaire. The dataset that represents the performance of alkaline chlorination was obtained from treatment batches with analytical sampling of each treated batch. This dataset achieved on average a 99.9% cyanide removal. The self-monitoring data submitted by Facility 30542 along with EPA-collected sampling data from this facility's system were used to develop the LTMs for cyanide based on hydrogen peroxide oxidation. The self-monitoring data submitted by Facility 30567 were used to develop the LTMs for cyanide based on alkaline chlorination.

Hydrogen Peroxide Oxidation treatment performance data from Facility 30542 were evaluated and those data points which represent an effluent cyanide concentration in excess of 1.0 mg/L were removed from the dataset that represents best performance. Four of 36 effluent data points were removed based on this criterion. These batches should have been recycled to cyanide destruction treatment but were discharged at the time of the data collection due to a false negative result from the facility's internal test procedure for cyanide which did not identify the effluent concentrations above the 1.0 mg/L target.

Alkaline Chlorination treatment performance data from Facility 30567 were evaluated. Only the datasets that showed 99% or more removal of cyanide were used as BAT treatment performance data. There were 256 datasets included in the treatment performance database and 46 effluent data points were removed based on this criterion. These batches should have been recycled to cyanide destruction treatment because they are not representative of BAT treatment performance. Table 8-6 presents the cyanide destruction treatment performance data.

8.3.6 Steam Stripping

The Agency collected steam stripping performance data from four EPA sampling episodes and from one EPA-sponsored pilot study.(5)(6)(7)(8)(9) The Agency also collected distillation performance data from one EPA-sponsored study.(10) In addition, the Agency received industry supplied steam stripping monitoring data from multiple facilities.

The data from these sampling episodes and treatability studies were evaluated against steam stripping treatment performance criteria. (32)

Only those constituents to be regulated were included in the database. All data points that were collected from a flash tank or distillation pot were excluded since these technologies are not considered "equivalent" to the BAT technology. Influent and effluent datasets where the influent concentration was not detected, showed a negative percent removal or that showed no removal after treatment were excluded. Data were excluded if collected while a stripper was not at steady state, because these data would not be representative of BAT performance. Steady state for the purpose of this comparison was defined as the point where temperatures and flow rates are constant. All data point pairs with an influent concentration lower than the long-term means shown in Table 8-19 were deleted. All data point pairs collected from a steam stripper with inadequate steam to feed ratios or an inadequate number of equilibrium stages in the stripper were deleted (see Table 10-7). Data which came from a single wastewater stream at one facility that was deemed to have an atypical matrix, i.e., did not lend itself to BAT performance, and were reported at a detection limit an order of magnitude or more than EPA's promulgated method minimum level, were not used.

The Agency received several comments arguing against the use of the distillation performance data collected by the Agency at proposal. The Agency performed an alcohol distillation pilot study at a pharmaceutical facility to represent optimum performance for the removal of alcohols and other compounds with similar strippability. Commenters argued that the wastewater stream evaluated in that study was not representative of "typical" pharmaceutical industry wastewater since it did not contain a mix of organic solvents, rather it was predominantly a methanol and water stream. In response to these comments, the Agency has not used this dataset in the determination of the final limitations and standards.

All other treatment performance data were then evaluated against the criteria listed above. Table 8-7 presents the data meeting these criteria for the steam stripping options. For organic constituents, treatment performance data do not indicate a difference in treatment based on

subcategory, and were considered together. These data are considered representative of treatment performance for all subcategories.

The Agency has also evaluated the use of air stripping for the removal of ammonia.(9) Since the average ammonia concentration of the plant wastewater stream for the air stripping study was significantly less than that expected, the Agency made three test runs at varying V/L ratios with plant wastewater spiked with ammonia. The optimum V/L ratio for ammonia stripping in these runs was found to be 510 cfm/gpm and the treatment performance data from this run represent well-designed/well-operated treatment performance for ammonia removal. The treatment performance data from this run are presented below. The Agency is transferring this air stripping treatment performance data to represent treatment achievable by steam stripping. Each of these technologies are based on the same mass transfer principals and steam stripping is a more effective treatment technology than air stripping since it is conducted at elevated temperatures at which ammonia is more volatile. Therefore, steam stripping will be as or more effective than air stripping in removing ammonia from wastewater. Table 8-8 presents the air stripping treatment performance data which are being used to represent treatment performance achievable by steam stripping.

The Agency received several comments arguing against the use of the ammonia air stripping pilot study performance data. EPA disagrees with these comments and maintains that the data collected from the air stripping study can be extrapolated to steam stripping limitations, since steam stripping will produce better removals than air stripping. The study was performed on-site at a pharmaceutical plant that produces a variety of products including products in the A, C, and D Subcategories.

EPA agrees that steam stripping performance is highly dependent on wastewater pH. The pilot study was performed for pH ranges between 10 and 12. The results of the pilot study show optimal air stripping performance between these levels. EPA expects that comparable ammonia removals from steam stripping at a lower pH will result in similar effluent concentrations as air stripping at a higher pH.

Additional steam stripping data from industry submitted after proposal show that under appropriate operating conditions (proper pH, steam to feed ratio, equilibrium temperatures, and sufficient stages) ammonia concentrations lower than the promulgated long-term mean can be achieved. In one data submittal from full-scale steam stripping operating data, the average influent ammonia concentration was 129 mg/L with effluent ammonia concentrations ranging from non-detect (<5 mg/L) to 5 mg/L. In a pilot steam stripping study data submittal, effluent ammonia concentration values were all non-detect.

8.4 Evaluation of Treatment Performance Data Transfers

The Agency does not have treatment performance data for all constituents and pollutant parameters promulgated for regulation. The Agency has transferred treatment performance data from constituents with data to constituents without data that are deemed to be treated similarly. The transferred data are being used to develop limitations and standards for pollutants for which EPA does not have data. This discusses the treatment performance data transfers used by the Agency.

8.4.1 Advanced Biological Treatment Performance Data Transfers

As shown in Table 8-2, EPA has performance data from advanced biological treatment for 24 organic constituents. To develop a basis of transfer for the 25 organic constituents considered for regulation for which EPA does not have sufficient performance data, the Agency grouped the organic constituents by structural and biodegradability groups and identified data transfers within these groups.

The organic constituents selected for regulation were grouped by biodegradability, including "high", "medium", and "low" biodegradability. These biodegradability groups were developed using K_{max} values and the ratio of BOD_5 to theoretical oxygen demand ($BOD_5/ThOD$). The K_{max} biodegradation rate is based on Monod-type kinetics, which assumes that biodegradation of any one constituent is independent of the concentrations of other constituents as long as no constituents are inhibitory or toxic to the microorganisms. Inhibition or toxicity by one

constituent may slow or halt the degradation of other constituents. As the K_{max} value increases, biodegradability increases. Large values of the ratio $BOD_5/ThOD$ (e.g., >50%) indicate that the compound is readily biodegradable. Low ratios (e.g., < 20%) indicate that the compound is either slowly biodegradable or only partially biodegradable.(13)

Constituents were placed in the "high" biodegradability group if the K_{max} value was greater than 4.00×10^{-6} or the $BOD_5/ThOD$ ratio was greater than 50%. Because neither a K_{max} value nor a $BOD_5/ThOD$ ratio were found for methyl formate, this constituent was placed in the "high" group due to its similar structure to ethyl acetate which is in the "high" group.

Constituents were placed in the "medium" biodegradability group if there was a broad range of $BOD_5/ThOD$ ratios (e.g., a $BOD_5/ThOD$ ratio between 20% and 70%). Constituents were also placed in the "medium" biodegradability group if the K_{max} value was greater than 1.00×10^{-7} and less than 4.00×10^{-6} . Because K_{max} values and $BOD_5/ThOD$ ratios were not found for diethylamine, 2-methylpyridine, and triethylamine, these constituents were placed in the "medium" group, based on the following information:

- Literature suggests biodegradability of diethylamine, but reports it is inhibitory to bacterial and algal cell division (14);
- 2-methylpyridine is very similar in structure to pyridine, which is in the "high" group; however, 2-methylpyridine was placed in the "medium" group because the extra methyl group of this constituent makes it less biodegradable (16); and
- A 200 mg/L solution of triethylamine is 100% biodegraded but triethylamine is also reported to be 50% inhibitory to nitrifying bacteria.(15)

Constituents were placed in the "low" biodegradability group if the K_{max} value was less than 1.00×10^{-7} or $BOD_5/ThOD$ ratios were less than 20%. Because K_{max} values and $BOD_5/ThOD$ ratios were not found for amyl alcohol, formamide, and N,N-dimethylacetamide, these constituents were placed in the "low" group, based on the following information:

- Very slow biodegradation has been shown for amyl alcohol. An activated sludge unit demonstrated only 3.7% removal of ThOD of this compound in 24 hours.(15)
- Very slow biodegradation has been shown for formamide. An activated sludge unit demonstrated only 11.8% removal of ThOD of this compound in 24 hours.(15)
- N,N-Dimethylacetamide was placed in the "low" group due to its structural similarity to formamide.(15)

Table 8-9 presents the structural and biodegradability groups for the organic constituents and ammonia for which EPA has best performance data and for the other organic constituents selected for regulation without best performance data.

8.4.1.1 Data Transfer Methodology

Once the biodegradability groups were assigned, appropriate data transfers were identified whereby treatment performance data were transferred from constituents with data to constituents for which the Agency did not have treatment performance data. Transfers were made between structurally similar constituents from within the same structural group (with the exception of the amines and those constituents without treatment performance data in the miscellaneous group). Transfers were made from less treatable to more treatable constituents, based on their biodegradability groupings and general guidelines regarding biological treatability (i.e., decreasing biodegradability with increased branching or shortening of carbon chains).(16) Table 8-9 presents the biological treatment performance data transfers. For some of the constituents listed in Table 8-9, treatment performance data were not available, and transfers of long-term means were not identified using the general methodology outlined above. Treatment performance data transfers were developed for these constituents based on the following methodology: transfers were still based on structural similarity, although a few of the transfers were not between constituents from the same structural group. Where more than one constituent was a candidate from which to transfer a long-term mean performance level, the constituent with the higher long-term mean was chosen. All of these transfers were between constituents that are similar in terms of relative biodegradability. The specific rationale supporting each data transfer is discussed below.

8.4.1.2 Alcohol Structural Group

The data transfers within the alcohol structural group are from ethanol to ethylene glycol, tert-butyl alcohol, n-butyl alcohol, n-propanol, and amyl alcohol. In addition to having similar structures, ethylene glycol was included in the high biodegradability group while ethanol was included in the medium biodegradability group, suggesting a transfer of data from a more treatable to a less treatable constituent. Both n-propanol and amyl alcohol have similar structures to ethanol and have longer carbon chains, suggesting easier biodegradability. The transfer from ethanol to tert-butyl alcohol and n-butyl alcohol is based on structural similarity.

8.4.1.3 Aldehyde Structural Group

The data transfer within the aldehyde structural group is from formaldehyde to isobutyraldehyde. Isobutyraldehyde has a longer carbon chain attached to the carbonyl group, which should enhance its biodegradability. The ratio of BOD₅ to ThOD is 65% for isobutyraldehyde compared to 60% for formaldehyde, indicating isobutyraldehyde is as biodegradable as formaldehyde, thereby supporting this transfer.

8.4.1.4 Amide Structural Group

Within the amide structural group, the data transfers are from N,N-dimethylformamide to N,N-dimethylacetamide and formamide. For N,N-dimethylacetamide, the additional methyl group attached to the acetamide should make it more biodegradable than N,N-dimethylformamide. For formamide, N,N-dimethylformamide is the most structurally similar constituent to this amide for which data are available.

8.4.1.5 Amine Structural Group

The amide, N,N-dimethylformamide, is used as the source of data transfer for diethylamine and triethylamine, since their structures are very similar. Both amines are less branched than N,N-dimethylformamide and, therefore, predicted to be more biodegradable than N,N-dimethylformamide.

8.4.1.6 Aromatic Structural Group

Within the aromatic structural group, data transfers are from 2-methylpyridine to aniline, N,N-dimethylaniline, chlorobenzene, pyridine, and o-dichlorobenzene. Aniline and pyridine, which are in the high biodegradability group, are predicted to be more biodegradable than 2-methylpyridine, which is in the medium biodegradability group. o-Dichlorobenzene and chlorobenzene, which are in the medium biodegradability group, are predicted to be as biodegradable as 2-methylpyridine, which is also in the medium biodegradability group. The other data transfer is based on the fact that N,N-dimethylaniline is closest in structure to 2-methylpyridine, an aromatic constituent for which treatment performance data are available.

8.4.1.7 Ester Structural Group

Data transfers in the ester structural group are from isopropyl acetate to n-butyl acetate and from ethyl acetate to n-amyl acetate and methyl formate. For all three transfers, the constituent transferred to is less complex and/or has a longer carbon chain attached to the ester group, making it easier to biodegrade.

8.4.1.8 Ether Structural Group

In the ether structural group, data transfers are from tetrahydrofuran to polyethylene glycol 600, 1,4-dioxane, and isopropyl ether. The transfer from tetrahydrofuran to 1,4-dioxane is based on the structural similarity of these constituents and the more highly branched structure of tetrahydrofuran. Both constituents have the same K_{max} value, also supporting the rationale that

1,4-dioxane should be at least as biodegradable as tetrahydrofuran. Tetrahydrofuran was chosen as the transfer basis for the other ethers without available treatment performance data since these constituents have similar structures.

8.4.1.9 Ketone and Alkane Structural Groups

In the ketone and alkane structural groups, data transfers are from acetone to methyl isobutyl ketone (MIBK) and from n-hexane to petroleum naphtha. MIBK and acetone are in the same structural group and both are considered highly biodegradable. Also MIBK has a greater K_{max} value than acetone, suggesting easier biodegradability for MIBK. N-hexane, an alkane, is the most structurally similar compound with performance data to petroleum naphtha. Petroleum naphtha is actually a petroleum distillate fraction containing a mixture of aromatic and straight chain hydrocarbons, with characteristics similar to both alkanes and aromatics.

8.4.1.10 Miscellaneous Structural Group

From the miscellaneous structural group, treatment performance data transfers are from ethanol to methyl cellosolve and from chloromethane to dimethyl sulfoxide. In each case, data were transferred from the most structurally similar constituent or group of constituents for which performance data are available.

8.4.2 Steam Stripping Treatment Performance Data Transfers

The Agency has treatment performance data from well-designed/well-operated steam stripping units for ten potentially regulated organic constituents. The ten candidate pollutants for regulation were used to develop a basis of performance data transfer for the other 27 potentially regulated organic constituents, by grouping all organic constituents into strippability groups based on their Henry's Law Constant. Data transfers were then made within each group from the least strippable compound to more strippable compounds.

Long term means were calculated for the ten potentially regulated pollutants from well-designed/well-operated steam stripping data. The calculated long-term means were then transferred to other pollutants within strippability groups. The Agency assigned long-term means for every potentially regulated pollutant; although, not every pollutant with a steam stripping long-term mean is necessarily being regulated under the promulgated steam stripping option. The POTW pass-through analysis precluded some of the pollutants with well-designed/well-operated steam stripping performance data from regulation. These pollutants are discussed within the context of steam stripping treatment performance data even though they are not regulated pollutants by the selected steam stripping option.

Henry's Law is used to relate the equilibrium of the vapor-phase concentration of a solute to its liquid-phase concentration. In its traditional formulation, shown in Equation 8-1, Henry's Law expresses vapor-liquid equilibrium when the total pressure is low (less than 2 atm) and when the solute concentration is also low (less than 1 mol%).(19)

$$X_i \times H = Y_i \times P \quad (8-1)$$

Where:

X_i	=	solute liquid-phase mole fraction
H	=	Henry's Law Constant
Y_i	=	solute vapor-phase mole fraction
P	=	pressure.

While the solute concentration in the wastewater from facilities in the pharmaceutical manufacturing industry may be more than 1 mol%, Henry's Law Constants still provide a good measure of relative strippability, and can be used to rank the constituents and place them in strippability groups.

In environmental applications, Henry's Law is often used to relate the equilibrium vapor-phase concentration of a contaminant to its concentration in water. For a given contaminant in water, the Henry's Law Constant is directly proportional to the contaminant's vapor pressure and inversely proportional to its solubility. A contaminant with a high vapor pressure and low solubility in water has a high Henry's Law Constant. Conversely, a contaminant that has a low

vapor pressure and/or is very soluble in water has a low Henry's Law Constant. For all contaminants, the Henry's Law Constant is a function of temperature and pressure.

These fundamental relationships allow Henry's Law Constants to be used to judge how effective treatment technologies that rely on liquid-to-vapor mass transfer will be and to judge the relative effectiveness of these technologies on different constituents. For example, constituents with high Henry's Law Constants are easily removed from water by steam stripping, while constituents with low Henry's Law Constants are not.

Table 8-10 presents, for each potentially regulated organic constituent and ammonia, the Henry's Law Constant (presented in decreasing order), the structural group, and the transfer group for the steam stripping option. In many cases, differing Henry's Law Constants for the same constituent were reported in differing data sources. In cases where different values were reported, those values presented in the EPA literature sources (20) or values from EPA's Surface Impoundment Modeling System (SIMS) database (18) were generally chosen as the preferred values. If no values were listed in any of these sources, then values were chosen from other sources based on best engineering judgment. All reported values for Henry's Law Constant are at 25°C and 1 atm (760 mmHg).

No Henry's Law Constants were found for polyethylene glycol 600 (PEG 600) and petroleum naphtha. PEG 600 is a mixture of condensation polymers of ethylene glycol with an average molecular weight of 600. The Henry's Law Constant for ethylene glycol, the "building block" of this polymer, was transferred to PEG 600 due to structural similarity. Petroleum naphtha is not a specific compound but a cut of petroleum that distills within a certain temperature range. Based on best engineering judgment, petroleum naphtha was placed in the "low" strippability group. The Henry's Law Constant for petroleum naphtha was transferred from the constituent with the lowest Henry's Law Constant in the "low" strippability group.

EPA has determined based on the Henry's Law constants and physical properties that eight of the constituents listed in Table 8-10 are not strippable. These constituents cannot be effectively treated by steam stripping and, therefore, do not have treatment performance data associated with

stripping treatment. These constituents may be regulated under regulatory options which include biotreatment but will not be regulated under regulatory options that include only steam stripping.

Sections 8.4.2.1 through 8.4.2.3 describe the steam stripping option treatment performance data transfers within each treatability group and the basic rationale behind each data transfer.

8.4.2.1 High Treatability Group

Three constituents with treatment performance data are included in the high treatability group, containing constituents which are easiest to strip. These constituents are chloroform, methylene chloride, and toluene. The long-term mean treatment performance level for methylene chloride, the least strippable of the constituents in the high treatability group, was transferred to the other, more strippable constituents in the high treatability group without treatment performance data. The long-term mean treatment performance level for methylene chloride is 0.20 mg/L.

8.4.2.2 Medium Treatability Group

Three constituents with treatment performance data, acetone, 2-butanone (also referred to as methyl ethyl ketone), and tetrahydrofuran are included in the medium treatability group. The long-term mean treatment performance level for acetone, the least strippable of the constituents in the medium treatability group, was transferred to the other, more strippable constituents in the medium treatability group without treatment performance data. The long-term mean treatment performance level for acetone is 4.1 mg/L under the steam stripping option.

8.4.2.3 Low Treatability Group

Treatment performance data are available for four constituents in the low treatability group: isopropanol, ethanol, pyridine, and methanol. The treatment performance data for isopropanol was transferred to more strippable constituents in the low treatability group for which treatment performance data are not available. The long-term mean treatment performance level for isopropanol is 11.8 mg/L. The treatment performance data for ethanol was transferred to n-

propanol. The long-term mean treatment performance data for ethanol is 355 mg/L. Treatment performance data for methanol were transferred to the remaining constituents in the low treatability group for which no data were available. The long-term mean treatment performance level for methanol is 1,240 mg/L.

8.4.3 ASPEN Simulation Modeling to Support Steam Stripping Treatment Performance Data Transfers

This provides technical support for the data transfers made in developing the long-term mean treatment performance levels for the steam stripping treatment option. In particular, this focuses on how process modeling was used to support the data transfers. 8.4.3.1 provides a general overview of the ASPEN simulation model. 8.4.3.2 describes the methodology used for supporting data transfers for steam stripping. The results of the ASPEN simulations are presented in 8.4.3.3. ASPEN simulations were performed using a steam stripping design similar to the designs forming the basis of the final regulations. The relative behavior demonstrated in these simulations document that constituents within the same stripping group can achieve equivalent or similar effluent concentrations.

8.4.3.1 Overview of ASPEN

Since the 1970s, the process industries (chemical, petroleum, pharmaceutical, etc.) have increasingly relied on computer models to design and predict the performance of process equipment. The types of models typically used in these industries for this task are not statistical or empirical, but rely on engineering fundamentals such as the principles of thermodynamics and unit operations.

Two process models (also called process simulators) were used to support the development of the pharmaceutical manufacturing effluent guidelines: ASPEN/SP™ (Version 7.0) and ASPEN Plus™ (Version 8.5), commercial process design programs available respectively from Simulation Sciences, Inc. and Aspen Technologies, Inc. Both programs are descendants of the original ASPEN program which was developed at MIT during the period of 1976-1981 under the

sponsorship of the Department of Energy and 55 industrial participants. Both programs give similar results and are widely accepted in industry for modeling chemical, petroleum, and environmental processes.

Key features of process simulation packages like ASPEN/SP™ and ASPEN Plus™ include the following:

- A large database of compounds and their properties which allow for modeling a wide range of processes;
- An extensive library of thermodynamic models (equations of state and activity coefficient models) for calculating the properties of mixtures; and
- A wide range of computer algorithms for modeling unit operations such as mixers, reactors, absorbers, strippers, and distillation columns.

8.4.3.2 Methodology for Data Transfer Simulations

As discussed previously, effluent data were collected on actual operating columns and pilot columns treating pharmaceutical manufacturing wastewater. For those pollutants where treatment performance data were not available, data were transferred from pollutants for which data were collected. The approach to making data transfers was two-part:

- 1) Transfers were made based on the physical properties that determine strippability, and
- 2) The proposed transfers were checked by simulating typical stripping systems using the ASPEN process simulators.

In using the ASPEN programs to support the data transfers, a five-step methodology was followed:

- 1) Each of the pollutants to be regulated was placed in one of seven strippability categories, with Group 1 representing pollutants that are most strippable and Group 7 representing pollutants that are not strippable.

- 2) Simple flowsheets for typical stripping systems were developed and the appropriate unit-operations models were selected.
- 3) Values were assumed for the key process variables (number of equilibrium stages and liquid to vapor (L/V) ratio). These key inputs vary among strippability groups because less strippable pollutants will operate at lower L/V ratios and require more stages. Influent concentrations for each pollutant were based on the maximum and average loadings reported in the Detailed Questionnaire.
- 4) The thermodynamic models for liquid-vapor equilibrium calculations were selected. To model the nonideal nature of most pollutants in water, an activity coefficient model was used.
- 5) The results of steps 1 through 4 were developed into simulation input files. Simulations were then run to determine if the transferred long-term mean performance level could be met by each pollutant assuming it was present at its maximum and average loading. If the long-term mean performance level could be met with either the maximum or average influent loading, the data transfer was considered acceptable. Note that in all cases the long-term mean performance level could be met at the maximum influent loads by increasing the number of stages or decreasing the L/V ratio assumed under step 3 (thus, ability to achieve performance levels is independent of feed concentrations for a given constituent).

8.4.3.3 Strippability Groups

As discussed above, each of the pollutants proposed for regulation was placed in one of seven strippability groups. Placement was based on published Henry's Law Constants at 25°C and 1 atm. Table 8-11 presents these categories and the pollutants in each group. Note that these groups are different than the data transfer groups presented in Table 8-10, as they have been established for a different purpose. The data transfer groups presented in Table 8-10 were established for the purpose of transferring direct measurement data. The strippability groups discussed here were established for the purpose of assigning key process design variables for simulation purposes, and for cost estimating purposes, as discussed in 10.3.5. However, the grouping presented in Table 8-10 and these presented here share two important characteristics: 1) both grouping systems are based on a ranking of pollutants by Henry's Law constant from

highest to lowest, and 2) pollutants considered not strippable are the same under both grouping systems.

8.4.3.4 Flowsheet Development

Two examples of typical steam stripping/distillation systems were identified: a stripper/decanter system for treating contaminants that have low water solubility and will form a phase-separable overhead product, and a distillation column with reflux for treating contaminants that are highly water soluble and will not likely form a phase-separable overhead product. Figures 8-1 and 8-2 illustrate these process configurations.

Process simulation flowsheets were developed for these configurations. For modeling contaminants that form a phase-separable overhead product, the flowsheet in Figure 8-3 was used. In this flowsheet, the stripper was modeled using the equilibrium-stage distillation algorithm in ASPEN, RADFRAC. The decanter was modeled using the three-phase flash algorithm, FLASH3, and the feed/effluent exchanger was modeled with the heater algorithm, HEATER.

For modeling situations where the contaminants are highly water soluble, the flowsheet shown in Figure 8-4 was used. A reflux ratio high enough to achieve a concentrated overhead product (contaminant weight percent ≥ 33) was assumed.

The key part of the ASPEN simulations is the column calculations. The RADFRAC model, which makes these calculations, is a general distillation model which uses the equilibrium-stage concept.(30) The required inputs to model a distillation column using the RADFRAC model are the feed wastewater flow rate, the steam flow rate, the pressure drop across the column, and the number of equilibrium stages. The algorithm used in RADFRAC makes simultaneous mass and energy balances at each stage. This algorithm is based on the "inside-out" concept developed by Boston.(30) The distillation, absorption, and stripping models used in most process simulators utilize this approach.

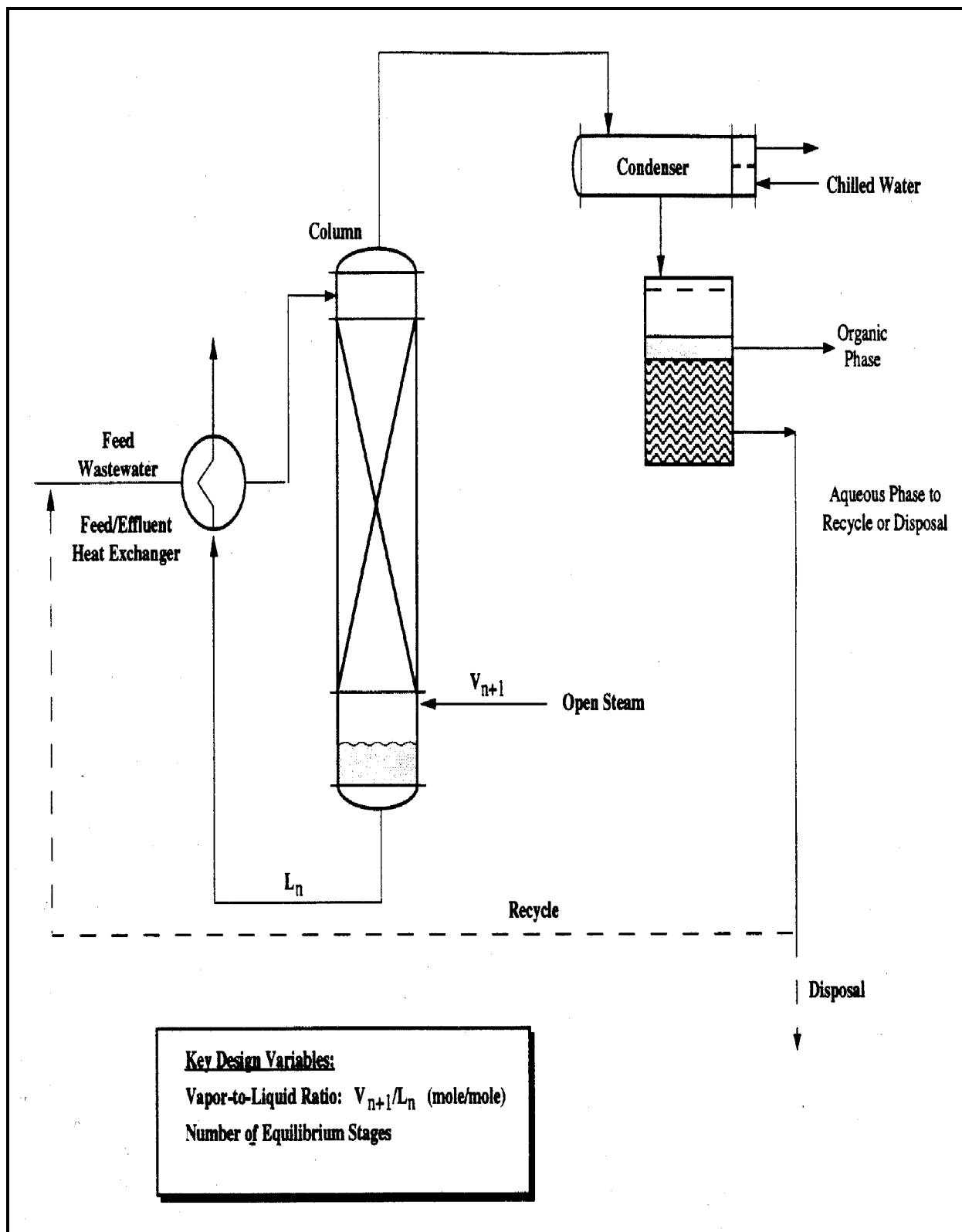


Figure 8-1. Process Schematic for a Steam Stripper with Open Steam

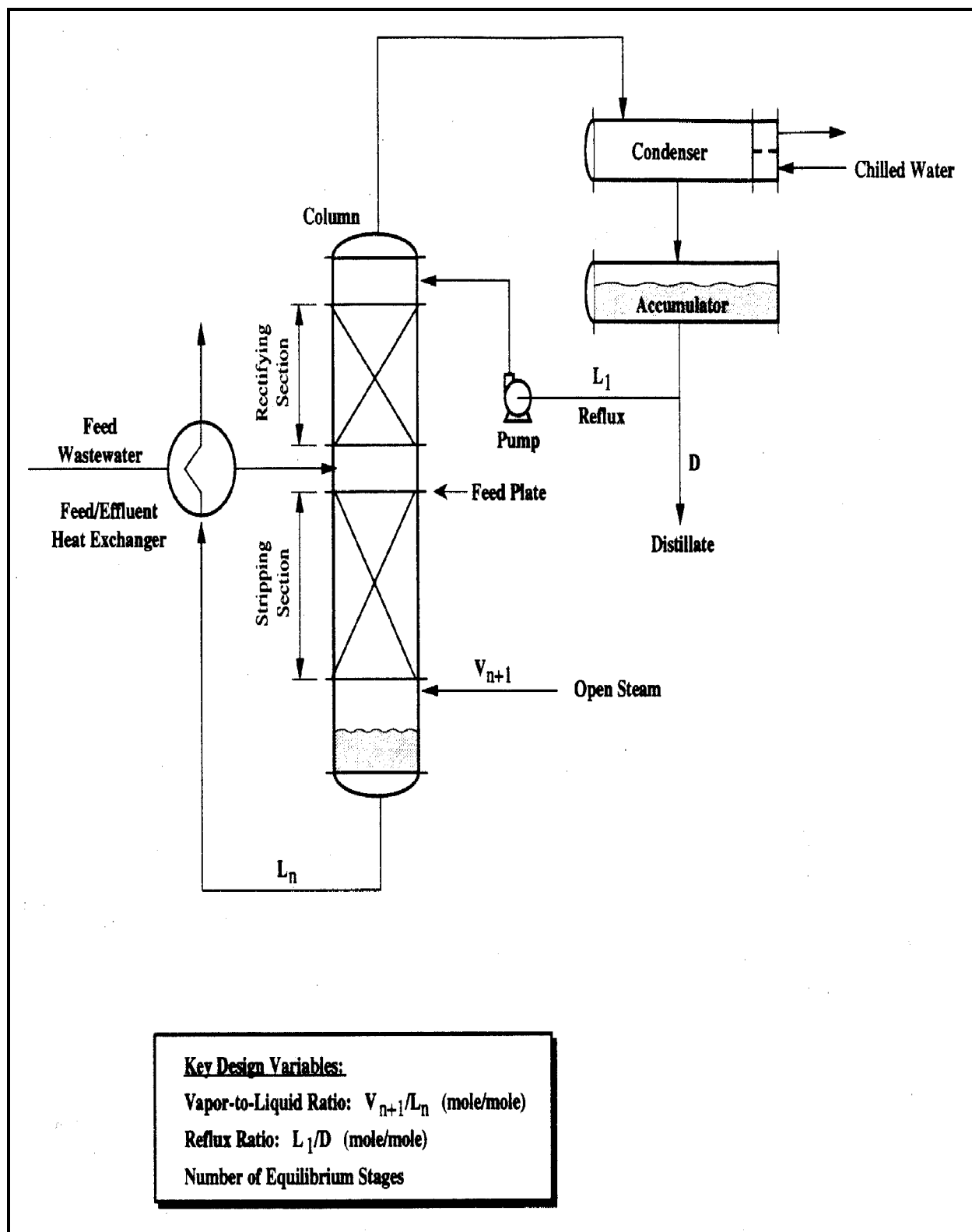


Figure 8-2. Process Schematic for a Distillation Column with Open Steam

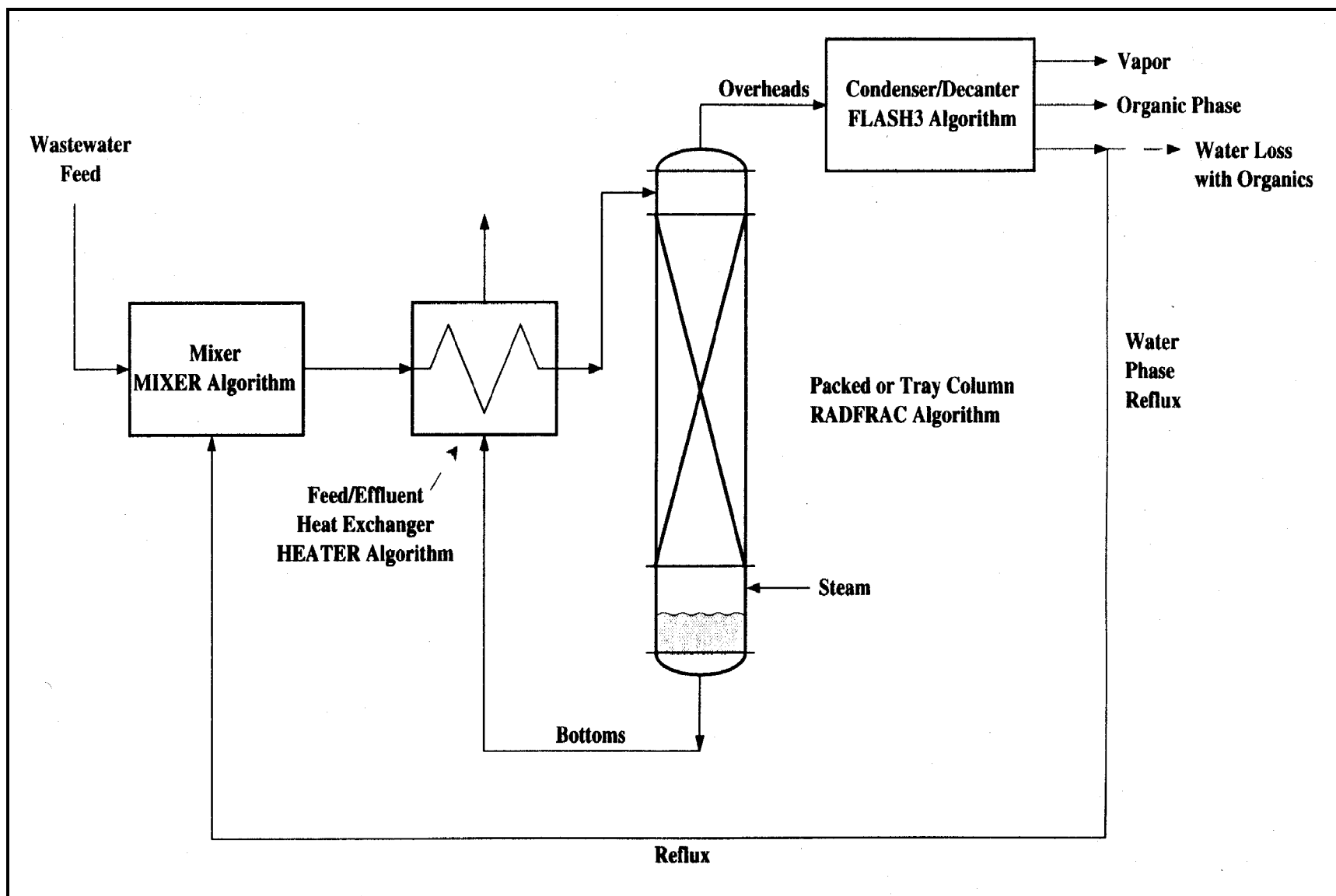


Figure 8-3. Simulation Block Diagram for Steam Stripper with Decanter

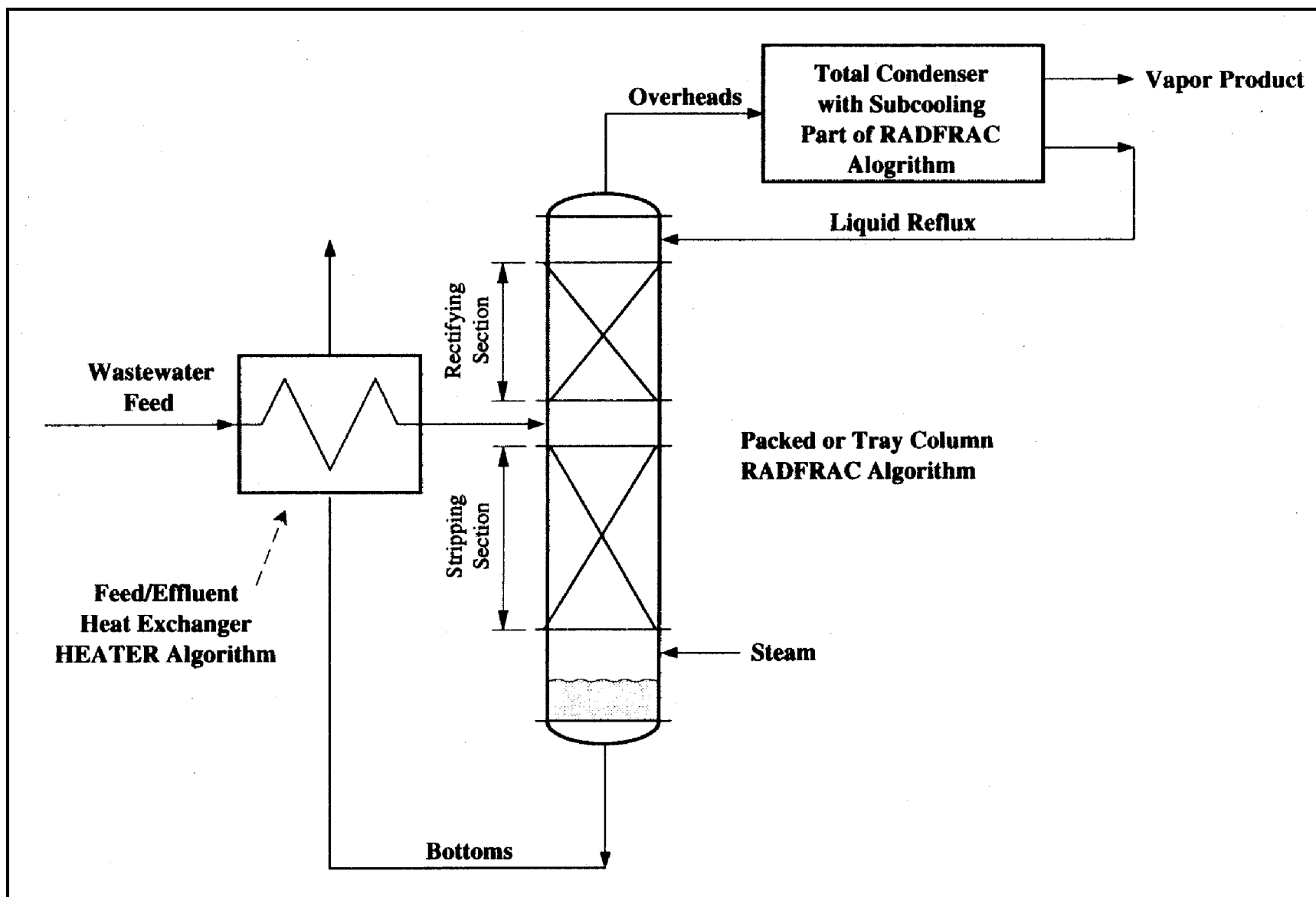


Figure 8-4. Simulation Block Diagram for Distillation Column with Open Steam

8.4.3.5 Estimation of Key Input Variables

As previously noted, the two most important process variables which determine the removal efficiency of a steam stripper or a distillation column are: 1) the number of equilibrium stages, and 2) the L/V ratio in the column. Table 8-12 presents the number of equilibrium stages and L/V ratios assumed for each strippability group. The assumed stages were chosen so that the total column height would be reasonable for a packed column assuming a height equivalent to one theoretical plate (HETP) of 2 to 3 feet. Two rectifying stages were assumed for strippability groups 3 through 6. The L/V ratios were then chosen to ensure high pollutant removal efficiencies. Other process inputs (feed water temperature, column pressure, condenser temperature, etc.) were based on typical industry values and are shown in Table 8-12. The values selected for these inputs will have less impact on the simulation results than the assumed number of stages or L/V ratio.

8.4.3.6 Selection of Thermodynamic Models

Since pharmaceutical manufacturing waste streams are generally nonideal mixtures, the liquid-vapor equilibrium calculations in the steam stripper simulations were performed using the UNiVersal QUAsi Chemical (UNIQUAC) activity coefficient model. The UNIQUAC model is one of many commonly used activity coefficient models. It is a widely accepted tool for modeling nonideal solutions.

The UNIQUAC model uses binary interaction parameters in its calculations. These parameters can be determined from experimental vapor-liquid equilibrium data or they can be estimated using the UNIFAC group contribution method. With the UNIFAC method, the binary interaction between two compounds is estimated from the interactions between the different functional groups that make up the two compounds. The UNIFAC database, which consists of values for the interaction parameters between different functional groups, is available in several references.(24,27) For the ASPEN/SPT[™] simulations performed, the binary interaction parameters for the UNIQUAC model were taken either from the DECHEMA data series (26) or generated using UNIFAC. The validity of using UNIFAC was confirmed by comparing calculated

K-values (estimated with ASPEN/SP™ using UNIFAC) to published K-values for several contaminants. Table 8-14 summarizes these results.

8.4.3.7 Summary of Simulation Results

Tables 8-15 and 8-16 present the results of the treatment performance data transfer simulation runs for Subcategory A and/or C facilities and Subcategory B and/or D facilities, respectively. These results show that simulating the average pollutant loading will result in an effluent concentration from steam stripping with distillation less than the pollutant's proposed long-term mean performance level for steam stripping with distillation. The Agency also found that in almost all cases simulating the maximum pollutant loading would also result in effluent concentrations less than the proposed long-term mean performance levels. Although ASPEN simulations were performed prior to proposal and were based on the proposed long-term mean performance levels for steam stripping with distillation, the methodology for determining pollutant transfers has not been modified for the final rule. Since transfers of experimental data were made from pollutants that are less strippable (i.e., a lower Henry's Law Constant) to pollutants that are more strippable, the effluent limitations guidelines should be attainable for all pollutants where well-designed, well-operated steam stripping and distillation columns are installed.

8.5 Long-Term Mean Development for Conventional Pollutant Parameters and COD

The conventional pollutants BOD₅ and TSS along with the nonconventional pollutant COD are controlled using advanced biological treatment under the regulatory options considered for the pharmaceutical manufacturing industry, as described in 7.

Using the treatment performance data presented in 8.3.1, a statistical analysis of the data was conducted to develop a long-term mean concentration and variability factors for BOD₅, TSS, and COD for advanced biological treatment. The results of this analysis are presented in Table 8-17. A detailed description of the statistical analysis and the results from this analysis are presented in

the Statistical Support Document for the Final Effluent Limitations Guidelines for the Pharmaceutical Manufacturing Industry (EPA-821-B-98-007) (hereafter referred to as the Statistical Support Document).

To develop the concentration-based long-term means and variability factors for each pollutant parameter, EPA modeled the concentration data using a modification of the delta-lognormal distribution. The modified delta-lognormal distribution model assumes that all nondetects occur at the detection limit and that the measured concentrations follow a lognormal distribution (i.e., the logarithms of the measured data are normally distributed). The modified delta-lognormal distribution is identical to a lognormal distribution if there are no nondetects in the data.

8.6 Long-Term Mean Development for Cyanide

For most of the regulatory options considered, as described in 7, cyanide limitations would not be revised, but the monitoring requirements would be clarified in Subcategories A and C and cyanide limitations would be withdrawn in Subcategories B and D.

For one of the PSES options considered, revised cyanide limitations were developed using the treatment performance data presented in 8.3.5. A statistical analysis of this data was conducted to develop a long-term mean concentration and variability factors for cyanide. For facilities using hydrogen peroxide oxidation, the long-term mean concentration developed for cyanide is 0.24 mg/L. For facilities using alkaline chlorination, the long term mean concentration developed for cyanide is 4.8 mg/L. A detailed description of the statistical analysis and the results from this analysis are presented in the Statistical Support Document.

EPA is not revising existing cyanide limitations or standards for Subcategories A and C because the new cyanide performance data indicate there would not be a large enough cyanide load removal to warrant changing the existing standard. EPA is clarifying that the existing cyanide limitations or standards must be met in-plant unless a facility can show a measurable cyanide load at end-of-pipe. The final regulation withdraws cyanide limitations or standards for subcategories B and D because cyanide is not present in the wastewaters of those subcategories.

8.7 Development of Long-Term Mean Concentrations for Priority and Nonconventional Pollutants

Sections 6.6 and 6.7 list the priority and nonconventional pollutants selected for regulation in the pharmaceutical manufacturing industry. Priority and nonconventional pollutants are controlled under the regulatory options considered for the pharmaceutical manufacturing industry described in 7, using either advanced biological treatment or steam stripping.

Using the treatment performance data presented in Sections 8.3.1 and 8.3.6, the Agency conducted a statistical analysis of the data to develop a long-term mean and variability factors for those priority and nonconventional pollutants with advanced biological and steam stripping treatment performance data. A detailed description of the statistical analysis and the results from this analysis are presented in the Statistical Support Document. Table 8-18 presents the long-term mean treatment performance concentrations developed for these pollutants using the datasets identified in Tables 8-2 and 8-7.

For priority and nonconventional pollutants without advanced biological or steam stripping treatment performance data, a transfer was applied as discussed in Section 8.4. Table 8-19 presents the long-term mean treatment performance concentrations for priority and nonconventional pollutants after application of the treatment performance data transfers.

8.8 Long-Term Mean Development for Ammonia

Ammonia is controlled under the regulatory options considered for the pharmaceutical manufacturing industry described in 7.

Advanced biological treatment with nitrification performance data for ammonia are presented in 8.3.2. Air stripping treatment performance data for ammonia are presented in 8.3.6; the air stripping data are being used to represent treatment achievable by steam stripping. A detailed description of the statistical analysis of these data and the results from this analysis are presented in the Statistical Support Document. EPA is not regulating ammonia for Subcategories B and D

because ammonia is not present in Subcategory B and D wastewaters at concentrations of concern.

The long-term mean treatment performance concentration developed for ammonia through advanced biological treatment with nitrification is 12.5 mg/L. The long-term mean treatment performance concentration for ammonia applicable to steam stripping treatment is 9.91 mg/L.

Table 8-1

Advanced Biological Treatment Performance Data for BOD₅, COD, and TSS

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30010	BOD ₅	10	2,080	971	3.0	695	47.6	600	SMD
	COD	157	3,750	2,030	31.0	1,904	296	951	SMD
	TSS	-	-	-	1.0	604	55.3	694	SMD
30540*	BOD ₅	230	9,730	2,440	11.0	528	98.4	1756	SMD
	COD	526	12,000	4,960	197	10,100	744	365	SMD
	TSS	-	-	-	16.3	2,710	155	365	SMD
30623	BOD ₅	566	5,880	2,520	0.8	19.7	4.7	356	SMD
	COD	986	11,600	5,080	27.9	189	98.3	51	SMD
	TSS	-	-	-	0.5	254	18.7	356	SMD
30637	BOD ₅	566	5,880	2,620	16.0	660	77.8	366	SMD
	COD	986	11,600	5,280	108.0	1,700	883	366	SMD
	TSS	-	-	-	8.0	577	106	366	SMD

* Data from facility 30540 has been corrected to account for the nonprocess water discharge after treatment.

Source:

SMD - Self-Monitoring Database, Reference (2).

Table 8-2

Advanced Biological Treatment Performance Data for Priority and Nonconventional Pollutants

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30540	Acetone	38.5	112	61.8	0.05	0.800	0.137	10	I
30540	Acetone	12.0	100	38.1	0.01	0.10	0.061	8	N
30623	Acetone	1.30	14.9	6.78	0.05	0.130	0.066	19	I
30623	Acetone	11.4	44.3	21.2	0.05	0.97	0.220	6	N
30540	Acetonitrile	2.0	8.80	4.06	0.050	0.10	0.090	5	N
30623	Acetonitrile	0.005	1.62	0.337	0.005	0.005	0.005	19	I
30623	Benzene	1.0	41.0	14.3	0.002	0.002	0.002	3	P
30623	2-Butanone (MEK)	13.7	107	35.7	0.050	0.065	0.051	19	I
30623	2-Butanone (MEK)	5.53	15.3	8.50	0.010	0.10	0.035	7	N
30050	Chloroform	0.554	1.62	1.09	0.001	0.001	0.001	3	V
30540	Chloroform	1.47	5.51	3.18	0.010	0.010	0.010	10	I
30540	Chloroform	0.840	3.40	1.92	0.0016	0.005	0.003	8	N
30623	Chloroform	1.00	16.0	6.3	0.009	0.018	0.013	3	P
30623	Chloroform	0.202	55.3	7.62	0.010	0.024	0.013	19	I

Table 8-2 (Continued)

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30010	Chloromethane (Methyl chloride)	8.00	13.0	10.1	0.10	0.41	0.29	3	V
30540	Chloromethane (Methyl chloride)	4.70	5.33	5.03	0.010	0.124	0.053	10	I
30540	Chloromethane (Methyl chloride)	0.500	6.50	2.93	0.001	0.010	0.007	8	N
30540	Cyclohexane	0.100	5.00	1.52	0.005	0.010	0.0075	8	N
30623	1,2-Dichloroethane	0.132	24.8	13.0	0.010	0.263	0.071	19	I
30623	1,2-Dichloroethane	1.00	5.00	2.67	0.002	0.110	0.038	3	P
30623	N,N-Dimethylformamide	0.10	113	49.8	0.010	0.035	0.011	20	I
30010	Ethanol	21.7	320	160	1.00	1.77	1.10	8	N
30540	Ethanol	124	209	161	0.500	5.51	1.00	10	I
30540	Ethanol	68.1	420	181	1.00	5.00	3.00	8	N
30623	Ethanol	10.6	1,320	253	0.500	0.800	0.530	20	I
30540	Ethyl acetate	40.0	77.1	57.9	0.500	0.600	0.510	10	I

Table 8-2 (Continued)

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30540	Ethyl acetate	0.18	50.0	11.0	0.005	0.010	0.0075	8	N
30623	Formaldehyde	0.300	6.50	1.75	0.120	0.800	0.343	19	I
30010	Formaldehyde	0.124	3.21	0.647	0.049	0.321	0.193	3	N
30623	Heptane	0.005	3.25	0.921	0.005	0.005	0.005	19	I
30623	Hexane	0.046	1.43	0.444	0.005	0.005	0.005	19	I
30623	Hexane	0.284	2.50	1.66	0.014	0.034	0.023	7	N
30540	Isopropanol	112	152	136	0.500	0.500	0.500	10	I
30540	Isopropanol	33.0	126	87.8	0.100	2.000	1.050	8	N
30540	Isopropyl acetate	26.4	112	68.1	0.500	0.500	0.500	10	I
30540	Isopropyl acetate	2.50	66.0	32.2	0.010	0.010	0.010	4	N
30010	Methanol	115	370	211	0.500	0.500	0.500	8	N
30540	Methanol	165	1,100	592	2.26	14.1	5.34	9	I
30540	Methanol	11.3	1,700	539	0.500	5.000	2.750	8	N
30623	Methanol	8.50	16,000	1,900	0.300	3.70	0.650	20	I

Table 8-2 (Continued)

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30623	Methylene chloride	1.00	264.0	91.0	0.004	0.110	0.069	3	P
30623	Methylene chloride	36.9	1,340	416	0.010	1.10	0.110	19	I
30623	Methylene chloride	0.431	6.11	1.94	0.010	0.68	0.097	8	N
30540	2-Methylpyridine	0.941	4.08	2.83	0.050	0.050	0.050	10	I
30540	2-Methylpyridine	0.161	1.60	0.643	0.010	0.011	0.011	8	N
30623	Phenol	0.010	0.651	0.169	0.010	0.022	0.011	7	I
30623	Tetrahydrofuran	1.59	75.0	25.4	0.005	3.48	1.22	9	I
30623	Tetrahydrofuran	1.68	7.88	5.35	0.007	1.36	0.048	8	N
30010	Toluene	56.0	71.0	61.3	0.010	0.010	0.010	3	V
30050	Toluene	0.078	0.193	0.131	0.001	0.001	0.001	3	V
30540	Toluene	0.146	0.484	0.311	0.010	0.010	0.010	10	I
30540	Toluene	0.410	3.00	1.26	0.005	0.006	0.0055	8	N
30623	Toluene	1.21	38.0	10.4	0.010	0.010	0.010	10	I
30623	Toluene	1.0	4.0	2.33	0.002	0.053	0.019	3	P
30623	Toluene	14.5	39.8	24.4	0.010	0.110	0.029	7	N

Table 8-2 (Continued)

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30540	Trichlorofluoromethane	1.32	2.25	1.77	0.010	0.043	0.018	10	I
30540	Total Xylenes	37.0	170	94.5	0.005	0.005	0.005	4	N

Sources:

I - EPA (List of Analytes) Sampling Program.

P - Facility Self-Monitoring Data from 1989 Pretest Questionnaires.

V - Verification Sampling Program.

N - Facility Sampling Program Submitted in Response to the Proposed Effluent Limitations and Guidelines.

Note: Values that were not detected were set at the detection limit.

Table 8-3

Nitrification Treatment Performance Data for Ammonia

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
Two-Stage System									
31040	Ammonia as N	1.0	533.0	166.0	1.0	167.0	15.2	529	A
30759	Ammonia as N	2.2	166.0	58.0	1.4	94.8	13.0	937	A
Single-Stage System									
30540	Ammonia as N	23.0	47.5	40.7	1.4	3.7	2.53	10	I
30669	Ammonia as N	33.0	338	181.28	1.0	155.0	15.05	115	N
30542	Ammonia as N	0.28	101	29.48	0.09	46.4	2.96	124	N

Sources: A = new data (post-NOA); I = EPA (List of Analytes) sampling; N= new data (post-proposal)

Table 8-4**Multimedia Filtration Treatment Performance Data for TSS**

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
50007	TSS	4.0	110	24.2	2.0	60.0	12.8	466	SMD
12053	TSS	5.5	106	26.2	0.40	35.0	6.84	84	SRI
12317	TSS	1.0	83.0	18.8	1.0	41.0	5.87	248	SRI

SMD - Self-Monitoring Database, Reference (2).

SRI - Self-Monitoring Database from the 10/27/83 NSPS proposed rule containing facility self-monitoring data from 1982 and 1983, Reference (4).

Note: Values that were not detected were set at the detection limit.

Table 8-5

Polishing Pond Treatment Performance Data for TSS

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
50007	TSS	4.0	158.0	30.4	4.0	110.0	24.2	462	SMD

SMD - Self-Monitoring Database, Reference (2).

Table 8-6

Cyanide Destruction Treatment Performance Data

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
Hydrogen Peroxide Oxidation									
30542	Cyanide	160.0	3,700.0	1,937.4	0.005	0.720	0.25	32	SMD/I
Alkaline Chlorination									
30567	Cyanide	6.0	28,568	7,307.94	0.02	26	4.767	210	SMD

SMD/I - Combined datasets from the Self-Monitoring Database and the EPA (List of Analytes) Sampling Program at Facility 30542, References (2), (3).

SMD - Self-Monitoring Database, Reference (2).

Table 8-7

**Well-Designed/Well-Operated Steam Stripping Treatment
Performance Data for Priority and Nonconventional Pollutants**

Facility-Stream	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30329-C	Acetone	977	20,000	3,750	0.730	103	32.3	20	N
30487-A	Acetone	59.1	151	89.0	0.818	5.84	2.65	23	I
30832-B	Acetone	1,800	9,700	5,220	7.80	1,800	732	5	N
31105-A	Acetone	78	78	78	0.050	0.050	0.050	5	N
31105-B	Acetone	340	340	340	0.069	16.0	4.07	4	N
60000-A	Acetone	731	769	746	0.197	0.769	0.389	8	I
60000-B	Acetone	1,100	1,570	1,290	1.22	9.68	5.61	8	I
30329-B	2-Butanone (MEK)	2,670	35,300	17,500	4.70	392	121	11	I
30329-C	Chloroform	42.1	1,000	330	0.040	0.091	0.046	16	N
60000-A	Chloroform	1,110	1,170	1,150	0.010	0.010	0.010	8	I
60000-B	Chloroform	228	600	370	0.010	0.010	0.010	8	I
60000-D	Chloroform	80.5	85.0	82.7	0.010	0.010	0.010	8	I
30329-B	Ethanol	1,190	28,100	13,400	102	1,330	693	11	I
30329-C	Ethanol	676	87,100	16,900	54.4	62,600	4,810	27	N
60000-A	Ethanol	345	660	479	0.500	0.500	0.500	8	I
60000-B	Ethanol	280	440	358	3.00	36.0	16.0	8	I

Table 8-7 (Continued)

Facility-Stream	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30329-C	Isopropanol	230	4,990	1,640	47.5	345	155	20	N
60000-A	Isopropanol	1,800	2,000	1,980	0.500	0.500	0.500	8	I
60000-B	Isopropanol	950	1,300	1,060	2.10	21.9	11.8	8	I
30329-C	Methanol	60,200	750,000	265,000	28,200	241,000	96,900	30	N
31105-A	Methanol	3,000	3,000	3,000	50.0	50.0	50.0	5	N
60000-A	Methanol	2,500	3,700	2,900	46.0	95.8	60.4	8	I
60000-B	Methanol	1,450	2,900	1,960	260	1,300	888	8	I
60000-D	Methanol	100,000	240,000	194,000	60,000	120,000	83,900	7	I
60000-E	Methanol	5,300	7,000	6,660	720	3,900	1,590	5	I
30329-C	Methylene chloride	83.8	10,000	2,510	0.060	4.60	0.329	25	N
30487-A	Methylene chloride	8.63	55.7	21.0	0.100	0.101	0.100	23	I
30618-A	Methylene chloride	9,060	12,800	10,300	1.00	1.00	1.00	13	I
30832-B	Methylene chloride	9,900	14,000	11,500	0.010	4.90	2.01	4	N
60000-A	Methylene chloride	17.1	19.0	18.3	0.010	0.398	0.106	8	I
60000-B	Methylene chloride	41.4	54.0	47.1	0.010	0.010	0.010	8	I
30329-C	Pyridine	1.20	760	118	0.790	180	43.1	9	N
30329-C	Tetrahydrofuran	1,000	9,000	3,290	0.700	1.40	0.750	14	N
30832-B	Tetrahydrofuran	5,300	13,000	9,230	0.500	130	66.2	3	N

Table 8-7 (Continued)

Facility-Stream	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Effluent Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
60000-E	Tetrahydrofuran	7,500	8,550	8,340	0.220	2.57	1.54	5	I
30329-B	Toluene	253	253	253	0.124	2.41	1.25	3	I
30329-C	Toluene	221	70,000	13,500	0.260	1,400	70.9	29	N
30487-A	Toluene	15.2	82.6	35.2	0.100	0.100	0.100	23	I
30832-A	Toluene	130	120,000	46,700	0.140	0.370	0.240	3	N
30832-B	Toluene	37	190	102	0.070	9.50	3.15	5	N
31105-A	Toluene	420	420	420	0.010	0.010	0.010	5	N
31105-B	Toluene	93	93	93	0.002	0.002	0.002	4	N
60000-A	Toluene	16.7	19.1	18.0	0.010	0.010	0.010	8	I
60000-B	Toluene	18.0	21.3	19.2	0.027	0.042	0.034	8	I
60000-D	Toluene	237	668	494	0.010	0.012	0.010	8	I
60000-E	Toluene	515	580	528	0.333	0.630	0.473	5	I

Sources:

I - EPA (List of Analytes) Sampling Program, Reference (3).

N - Facility Sampling Program submitted in response to the Proposed Effluent Limitations and Guidelines.

Note: Values that were not detected were set at the detection limit.

Table 8-8

Air Stripping Treatment Performance Data for Ammonia

Facility	Pollutant	Influent Conc. (mg/L)			Effluent Conc. (mg/L)			# of Data Points	Source
		Min.	Max.	Avg.	Min.	Max.	Avg.		
30329	Ammonia (aqueous)	123.0	128.0	125.0	8.1	11.2	9.9	7	PILOT

PILOT - EPA-sponsored pilot study of air stripping, Reference (9).

Table 8-9

Advanced Biological Treatment Performance Data Transfers

Constituent Code	Constituent Name	Kmax Value (a)	BOD ₅ /ThOD Ratio	Structural Group	Biodegradability Group	Constituent Transferred From
94	Isopropanol	4.89E-06	54%-83%	alcohol	high	Data available
70	Ethanol	2.45E-06	37%-74%	alcohol	medium	Data available
77	Ethylene glycol		63%	alcohol	high	Ethanol
114	Phenol	2.70E-05	70%	alcohol	high	Data available
29	tert-Butyl alcohol		0.8%	alcohol	medium	Ethanol
97	Methanol (Methyl alcohol)	5.00E-06	51%-75%	alcohol	high	Data available
27	n-Butanol	4.89E-06	33%-58%	alcohol	high	Ethanol
117	n-Propanol		20%-44%	alcohol	medium	Ethanol
11	Amyl alcohol			alcohol	low	Ethanol
79	Formaldehyde	1.39E-06	60%	aldehyde	high	Data available
93	Isobutyraldehyde		65.6%	aldehyde	high	Formaldehyde
60	N,N-Dimethylacetamide			amide	low	N,N-Dimethylformamide
80	Formamide			amide	low	N,N-Dimethylformamide
64	N,N-Dimethylformamide	2.70E-06		amide	medium	Data available
55	Diethylamine			amine	medium	N,N-Dimethylformamide
136	Triethylamine			amine	medium	N,N-Dimethylformamide
15	Benzene	5.28E-06	70%	aromatic	high	Data available
12	Aniline	1.97E-06	62%	aromatic	high	2-Methylpyridine

Table 8-9 (Continued)

Constituent Code	Constituent Name	Kmax Value (a)	BOD ₅ /ThOD Ratio	Structural Group	Biodegradability Group	Constituent Transferred From
62	N,N-Dimethylaniline		9.5%	aromatic	low	2-Methylpyridine
139	Xylenes	8.65E-06		aromatic	high	Data available
106	2-Methylpyridine			aromatic	medium	Data available
35	Chlorobenzene	1.10E-07	1%	aromatic	medium	2-Methylpyridine
124	Pyridine	4.89E-06	52%	aromatic	high	2-Methylpyridine
130	Toluene	2.04E-05	5%-69%	aromatic	high	Data available
48	o-Dichlorobenzene (1,2-Dichlorobenzene)	7.00E-07		aromatic	medium	2-Methylpyridine
51	1,2-Dichloroethane	5.83E-07	7%	chlorinated alkane	medium	Data available
39	Chloromethane (Methyl chloride)	8.30E-08		chlorinated alkane	low	Data available
134	Trichlorofluoromethane	3.00E-06		chlorinated alkane	medium	Data available
102	Methylene Chloride	6.11E-06		chlorinated alkane	high	Data available
37	Chloroform	8.20E-07	6%	chlorinated alkane	medium	Data available
26	n-Butyl acetate		7%-46%	ester	medium	Isopropyl acetate
71	Ethyl acetate	4.89E-06	16%-68%	ester	high	Data available
95	Isopropyl acetate		12.7%	ester	low	Data available
10	N-Amyl acetate	4.89E-06	38%	ester	high	Ethyl acetate
103	Methyl formate			ester	high	Ethyl acetate
115	Polyethylene glycol 600		0.6%	ether	low	Tetrahydrofuran
67	1,4-Dioxane	4.89E-06		ether	high	Tetrahydrofuran

Table 8-9 (Continued)

Constituent Code	Constituent Name	Kmax Value (a)	BOD ₅ /ThOD Ratio	Structural Group	Biodegradability Group	Constituent Transferred From
129	Tetrahydrofuran	4.89E-06		ether	high	Data available
96	Isopropyl ether		6.7%	ether	low	Tetrahydrofuran
105	Methyl isobutyl ketone (MIBK)	4.89E-06	4.4%-79%	ketone	high	Acetone
118	Acetone	3.61E-07	50%	ketone	high	Data available
25	2-Butanone (MEK)	5.60E-07	46%	ketone	medium	Data available
84	n-Heptane	4.25E-06		alkane	high	Data available
87	n-Hexane	4.25E-06	63%	alkane	high	Data available
43	Cyclohexane	4.25E-06		alkane	high	Data available
113	Petroleum naphtha			alkane		n-Hexane
3	Acetonitrile	5.00E-06		misc.	high	Data available
101	Methyl cellosolve		7.1%	misc.	low	Ethanol
9	Ammonia (aqueous)	2.70E-06		misc.	medium	Data available
66	Dimethyl sulfoxide			misc	low	Chloromethane

(a) Units for Kmax values are (gram constituent/gram biosludge/second)

Kmax values: Reference (18).

BOD₅/ThOD ratios: References (14), (15), (16), and (17).

Table 8-10

Steam Stripping Treatment Performance Data Transfers

Constituent Code	Constituent Name	Henry's Law Constant (atm/gmole/m ³)	Source	Structural Group	Transfer Group	Constituent Transferred From
84	N-Heptane	2.85E+00	(a)	n-alkane	high	Methylene chloride
87	N-Hexane	1.55E+00	(a)	n-alkane	high	Methylene chloride
130	Toluene	5.93E-03	(a)	aromatic	high	Data available
15	Benzene	5.55E-03	(c)	aromatic	high	Methylene chloride
139	Xylenes	5.10E-03	(a)	aromatic	high	Methylene chloride
35	Chlorobenzene	3.93E-03	(b)	aromatic	high	Methylene chloride
37	Chloroform	3.39E-03	(b)	chlorinated alkane	high	Data available
101	Methyl cellosolve	2.90E-03	(a)	misc.	high	Methylene chloride
102	Methylene chloride	2.68E-03	(a)	chlorinated alkane	high	Data available
96	Isopropyl ether	2.24E-03	(c)	ether	medium	Acetone
48	o-Dichlorobenzene (1,2-Dichlorobenzene)	1.94E-03	(b)	aromatic	medium	Acetone
51	1,2-Dichloroethane	1.10E-03	(c)	chlorinated alkane	medium	Acetone
26	N-Butyl acetate	4.68E-04	(a)	ester	medium	Acetone
10	N-Amyl acetate	3.91E-04	(a)	ester	medium	Acetone
9	Ammonia (aqueous)	3.28E-04	(b)	misc.	medium	Data available
95	Isopropyl acetate	3.17E-04	(e)	ester	medium	Acetone
93	Isobutyraldehyde	1.47E-04	(e)	aldehyde	medium	Acetone
136	Triethylamine	1.38E-04	(a)	amine	medium	Acetone
71	Ethyl acetate	1.20E-04	(c)	ester	medium	Acetone

Table 8-10 (Continued)

Constituent Code	Constituent Name	Henry's Law Constant (atm/gmole/m ³)	Source	Structural Group	Transfer Group	Constituent Transferred From
55	Diethylamine	1.10E-04	(a)	amine	medium	Acetone
129	Tetrahydrofuran	1.10E-04	(f)	ether	medium	Data available
105	MIBK	9.40E-05	(a)	ketone	medium	Acetone
103	Methyl formate	8.10E-05	(g)	ester	medium	Acetone
25	2-Butanone (MEK)	4.36E-05	(b)	ketone	medium	Data available
118	Acetone	3.67E-05	(a)	ketone	medium	Data available
11	Amyl alcohol	2.23E-05	(a)	alcohol	low	Isopropanol
80	Formamide	1.92E-05	(g)	amide	low	Isopropanol
62	N,N-Dimethylaniline	1.75E-05	(a)	aromatic	low	Isopropanol
29	tert-Butyl alcohol	1.17E-05	(a)	alcohol	low	Isopropanol
94	Isopropanol	8.07E-06	(a)	alcohol	low	Data available
117	n-Propanol	6.85E-06	(a)	alcohol	low	Ethanol
70	Ethanol	6.26E-06	(a)	alcohol	low	Data available
27	n-Butyl alcohol	5.57E-06	(a)	alcohol	low	Methanol
124	Pyridine	5.30E-06	(g)	aromatic	low	Data available
67	1,4-Dioxane	4.88E-06	(a)	ether	low	Methanol
12	Aniline	2.90E-06	(b,g)	aromatic	low	Methanol
113(I)	Petroleum naphtha	2.70E-06	(g)	misc.	low	Methanol
97	Methanol	2.70E-06	(b)	alcohol	low	Data available
114	Phenol	3.97E-07	(a)	alcohol	not strippable	-
79	Formaldehyde	3.27E-07	(a)	aldehyde	not strippable	-
3	Acetonitrile	2.01E-07	(a)	misc.	not strippable	-

Table 8-10 (Continued)

Constituent Code	Constituent Name	Henry's Law Constant (atm/gmole/m ³)	Source	Structural Group	Transfer Group	Constituent Transferred From
64	N,N-Dimethylformamide	1.29E-07	(g,h)	amide	not strippable	-
115(j)	Polyethylene glycol 600	1.08E-07	(g)	alcohol	not strippable	-
77	Ethylene glycol	1.08E-07	(e)	alcohol	not strippable	-
60	N,N-Dimethylacetamide	4.55E-08	(g,h)	amide	not strippable	-
66	Dimethyl sulfoxide	6.00E-09	(g,h)	misc.	not strippable	-

Sources:

- (a) EPA Literature Values, Reference (20).
- (b) SIMS Model Database, Reference (18).
- (c) Alternate EPA Literature Values, References (21), (22), and (23).
- (d) UNIFAC Value, Reference (24).
- (e) TSDF Air Emission Model, Reference (25).
- (f) Toxics Database.
- (g) Best Engineering Judgement.
- (h) DECHEMA, Reference (26).

Notes:

All values for Henry's Law Constant are at 25°C and 1 atm.

The LTM for constituents without data was transferred from the constituent with the lowest Henry's Law Constant in the transfer group except where noted.

Ammonia data are from air stripping treatment performance.

Table 8-11

**Strippability Groups for Potentially Regulated Compounds Established for
Assigning Process Design Variables for Steam Stripping Technology**

Compound/Group	Henry's Law Constant (atm/gmole/m ³)
Group 1	
n-Heptane	2.85E+00
n-Hexane	1.55E+00
Group 3	
Toluene	5.93E-03
Benzene	5.55E-03
Xylenes	5.10E-03
Chlorobenzene	3.93E-03
Chloroform	3.39E-03
Methyl cellosolve	2.90E-03
Methylene chloride	2.68E-03
Isopropyl ether	2.24E-03
o-Dichlorobenzene (1,2-Dichlorobenzene)	1.94E-03
1,2-Dichloroethane	1.10E-03
Group 4	
N-Butyl acetate	4.68E-04
N-Amyl acetate	3.91E-04
Ammonia (aqueous)	3.28E-04
Isopropyl acetate	3.17E-04
Isobutyraldehyde	1.47E-04
Triethylamine	1.38E-04
Ethyl acetate	1.20E-04
Diethylamine	1.10E-04
Tetrahydrofuran	1.10E-04
Methyl isobutyl ketone (MIBK)	9.40E-05
Methyl formate	8.10E-05
Group 5	
2-Butanone (MEK)	4.36E-05
Acetone	3.67E-05
Amyl alcohol	2.23E-05
Formamide	1.92E-05
N,N-Dimethylaniline	1.75E-05
tert-Butyl alcohol	1.17E-05
Isopropanol	8.07E-06

Table 8-11 (Continued)

Compound/Group	Henry's Law Constant (atm/gmole/m ³)
n-Propanol	6.85E-06
Ethanol	6.26E-06
n-Butyl alcohol	5.57E-08
Pyridine	5.30E-06
1,4-Dioxane	4.88E-06
Aniline	2.90E-06
Group 6	
Methanol	2.70E-06
Petroleum naphtha	2.70E-06
Group 7	
Phenol	3.97E-07
Formaldehyde	3.27E-07
Acetonitrile	2.01E-07
N,N-Dimethylformamide	1.29E-07
Polyethylene glycol 600	1.08E-07
Ethylene glycol	1.08E-07
N,N-Dimethylacetamide	4.55E-08
Dimethyl sulfoxide	6.00E-09

Table 8-12**Key Process Inputs for Data Transfer Simulations**

Strippability Group	Equilibrium Stages Total	Stripping Stages	L/V	V/L
1	4	4	12.0	0.083
2	4	4	12.0	0.083
3	6	4	10.0	0.100
4	10	8	7.5	0.133
5	14	12	4.0	0.250
6	14	12	3.0	0.333

Table 8-13**Secondary Process Inputs for Data Transfer Simulations**

Input	Value	Basis
Thermodynamics	Calculated	UNIQUAC/UNIFAC
Mass & Energy Balances	Calculated	Inside/Outside Algorithm by Boston
Steam Pressure	40 psig	Field Test Experience
Column Pressure Drop (includes delta P across condenser)	4 psig	Field Test Experience
Approach for Feed/Effluent HX ^(a) (Feed temperature of approximately 200°F)	20°F	Field Test Experience

(a) Approach for Feed/Effluent HX is the temperature difference between the inlet bottom temperature and the outlet temperature of the feed to the column.

Table 8-14**Comparison of UNIFAC K-Values and Literature K-Values
At 25°C In Water**

Chemical	K-Values ^(a)		Reference
	Estimated with UNIFAC	Literature Values	
Acetone	2.2	2.0	29
Chloroform	221.0	188.	25
Ethanol	0.5	0.3, 1.7	30/29
Isopropyl alcohol	2.1	0.4, 8.3	30/29
Methanol	0.1	0.2, 7.5	30/29
Methylene chloride	140.0	177.2	25
Methyl isobutyl ketone (MIBK)	3.4	2.8, 5.2	30/29
Tetrahydrofuran (THF)	6.4	6.1	30
Toluene	436.7	377.8	18

(a)The K-value of a compound in water at infinite dilution is referred to as the Henry's Law Constant of that compound.

Table 8-15

**Simulation Results Supporting Steam Stripping with Distillation Treatment
Performance Data Transfers for Subcategory A and C Facilities**

Compound Strippability Group	Estimated Influent^(a) (mg/L)	ASPEN Simulated Effluent^(b) (mg/L)	Proposed Long-Term Mean Performance Level (mg/L)
Group 1			
n-Heptane	242	<0.005	0.10
n-Hexane	16,600 (c)	<0.005	0.10
Group 3			
Toluene	4,760	<0.010	0.1
Benzene	46.2	<0.010	0.10
Xylenes	328	<0.010	0.10
Chlorobenzene	106	<0.010	0.10
Chloroform	257	<0.010	0.01
Methylene chloride	3,380 (c)	<0.010	0.10
Isopropyl ether	19.2	<0.050	0.39
1,2-Dichloroethane	575	<0.010	0.39
Group 4			
Tetrahydrofuran	1,820	<0.005	1.54
n-Butyl acetate	828	<0.500	0.39
n-Amyl acetate	2,870	<0.500	0.39
Isopropyl acetate	966	<0.500	0.39
Isobutyraldehyde	67.3	<0.180	0.39
Triethylamine	3,240	<0.050	0.39
Ethyl acetate	16,300	<0.500	0.39
Diethylamine	1,440	<0.010	0.39
Methyl isobutyl ketone (MIBK)	9,780	<0.005	0.39
Methyl formate	276	<0.500	0.50
Group 5			
Pyridine	1,110	0.247	1.00
2-Butanone	262	<0.050	25.8
Acetone	3,680	<0.050	0.39
Amyl alcohol	486	<0.500	1.52
N,N-Dimethylaniline	1,670	<0.050	1.52
tert-Butyl alcohol	254	<0.500	1.52
Isopropanol	3,190	<0.050	1.52
n-Propanol	261	<0.050	1.52

Table 8-15 (Continued)

Compound Strippability Group	Estimated Influent^(a) (mg/L)	ASPEN Simulated Effluent^(b) (mg/L)	Proposed Long-Term Mean Performance Level (mg/L)
Ethanol	28,900	0.697	1.52
n-Butyl alcohol	37,900	0.159	1.52
1,4-Dioxane	180	<0.050	1.52
Aniline	22.8	<0.010	1.52
Group 6			
Methanol	20,000 (d) (e)	1.040	1.52

- (a) All estimated influents are industry average unless otherwise noted.
(b) The < sign indicates estimated concentration is below detection limit.
(c) Simulated with concentration at solubility limit.
(d) Approximate concentration during field test.
(e) Influent is not an industry average.

Note: Simulations were not run for methyl cellosolve, formamide, and petroleum naphtha, since appropriate physical property data were not available.

Table 8-16

**Simulation Results Supporting Steam Stripping with Distillation Treatment
Performance Data Transfers for Subcategory B and D Facilities**

Compound/Group	Estimated Influent (mg/L)	Estimated Influent is an Industry Average (A)	ASPEN Simulated Effluent(a) (mg/L)	Proposed Long-Term Mean Performance Level (mg/L)
Group 1				
n-Hexane	423	A	<0.005	0.10
Group 3				
Toluene	66.1	A	<0.010	0.10
Chloroform	7.8	A	<0.010	0.01
Methylene chloride	3,380	A (b)	<0.010	0.10
Isopropyl ether	28.3	A	<0.050	0.10
Group 4				
N-Amyl acetate	400	A	<0.500	0.39
Isopropyl acetate	110	A	<0.500	0.39
Triethylamine	<0.1	A	<0.050	0.39
Ethyl acetate	1,070	A	<0.500	0.39
Group 5				
Pyridine	45.0	A	0.2	1.00
Acetone	42,700	A	<0.050	0.39
Isopropanol	2,650	A	<0.050	1.52
Ethanol	2,920	A	0.7	1.52
n-Butyl alcohol	7.3	A	0.2	1.52
Group 6				
Methanol	20,000	(b)	1.0	1.52

(a) The < sign indicates estimated concentration is below detection limit.

(b) Simulated with concentration at solubility limit.

(c) Approximate concentration during field test.

Note: Simulations were run for those regulated constituents with raw loads reported in the Detailed Questionnaire.

Table 8-17

**Long-Term Mean Treatment Performance Concentrations
for BOD₅, COD, and TSS in Advanced Biological Treatment**

Subcategory Discharge Status	Long-Term Mean Concentration (mg/L)		
	BOD₅	COD	TSS
A and C/Direct	74.3*	637	105*
B and D/Direct	13.5*	55.4	23.4*

*Only applicable to NSPS

Table 8-18

Long-Term Mean Treatment Performance Concentrations for Priority and Nonconventional Pollutants with Available Data

Pollutant Code	Pollutant	Long-Term Mean Concentration (mg/L)	
		Adv. Biological Treatment	Steam Stripping
118	Acetone	0.101	4.1
003	Acetonitrile	0.048	-
009	Ammonia (aqueous)	12.5	9.9
015	Benzene	0.002	-
025	2-Butanone (MEK)	0.043	121
037	Chloroform	0.010	0.010
039	Chloromethane (Methyl chloride)	0.053	-
043	Cyclohexane	0.008	-
051	1,2-Dichloroethane	0.055	-
064	N,N-Dimethylformamide	0.011	-
070	Ethanol	1.10	355
071	Ethyl acetate	0.259	-
079	Formaldehyde	0.268	-
084	n-Heptane	0.005	-
087	n-Hexane	0.014	-
094	Isopropanol	0.775	11.8
095	Isopropyl acetate	0.255	-
097	Methanol	1.70	0.218
102	Methylene chloride	0.097	0.20
106	2-Methylpyridine	0.030	
114	Phenol	0.011	-
124	Pyridine	-	43.1
129	Tetrahydrofuran	0.784	1.5
130	Toluene	0.010	0.100
134	Trichlorofluoromethane	0.018	-
139	Xylenes	0.005	-

A dash indicates treatment performance data for a specific technology is not available.

Table 8-19

**Long-Term Mean Treatment Performance Concentrations for
Priority and Nonconventional Pollutants
(Including Treatment Performance Data Transfers)**

Pollutant Code	Pollutant	Long-Term Mean Concentration (mg/L)	
		Adv. Biological Treatment	Steam Stripping
118	Acetone	0.101	4.1
003	Acetonitrile	5.0*	NS
009	Ammonia (aqueous)	12.5	9.9
010	n-Amyl acetate	0.259	4.1
011	Amyl alcohol	2.0	11.8
012	Aniline	0.030	1,240
015	Benzene	0.010*	0.218
025	2-Butanone (MEK)	0.05*	121
026	n-Butyl acetate	0.255	4.1
027	n-Butyl alcohol	2.0	1,240
029	tert-Butyl alcohol	2.0	11.8
035	Chlorobenzene	0.030	0.218
037	Chloroform	0.010	0.010
048	o-Dichlorobenzene (1,2-Dichlorobenzene)	0.030	4.1
051	1,2-Dichloroethane	0.055	4.1
055	Diethylamine	50*	50*
060	N,N-Dimethylacetamide	0.05*	NS
062	N,N-Dimethylaniline	0.030	11.8
064	N,N-Dimethylformamide	0.011	NS
066	Dimethyl sulfoxide	20*	NS
067	1,4-Dioxane	0.784	1,240
070	Ethanol	2.0*	355
071	Ethyl acetate	0.259	4.1
077	Ethylene glycol	2.0	NS
079	Formaldehyde	0.268	NS
080	Formamide	100*	100*
084	n-Heptane	0.010*	0.218
087	n-Hexane	0.014	0.218

Table 8-19 (Continued)

Pollutant Code	Pollutant	Long-Term Mean Concentration (mg/L)	
		Adv. Biological Treatment	Steam Stripping
093	Isobutyraldehyde	0.268	4.1
094	Isopropanol	0.775	11.8
095	Isopropyl acetate	0.255	4.1
096	Isopropyl ether	0.784	4.1
097	Methanol	2.0*	1,240
101	Methyl cellosolve	20*	20*
102	Methylene chloride	0.097	0.218
103	Methyl formate	0.259	4.1
105	Methyl isobutyl ketone (MIBK)	0.101	4.1
113	Petroleum naphtha	0.03*	1,240
114	Phenol	0.011	NS
115	Polyethylene glycol 600	1.0*	NS
117	n-Propanol	2.0	355
124	Pyridine	0.030	43.1
129	Tetrahydrofuran	0.784	1.5
130	Toluene	0.010	0.100
136	Triethylamine	50*	50*
139	Xylenes	0.005	0.218

NS - Constituent is not strippable.

* - Long-term mean concentration set at ML for pollutant.

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